CLAIMS

1. A plasma-generation power-supply device that drives a discharging load (1) that generates a plasma, comprising:

an alternating-current power-supply (IV) that supplies power to said discharging load; and

a controller (CT) that is capable of controlling a frequency of an alternating output of said alternating-current power-supply,

said controller (CT) providing control to vary the power-supply frequency of said alternating-current power-supply (IV) in accordance with a target applied power to said discharging load (1).

2. The plasma-generation power-supply device according to claim 1, wherein said controller (CT) controls said power-supply frequency such that current is delayed in phase with respect to voltage at a power-supply output end of said alternating-current power-supply (IV).

3. The plasma-generation power-supply device according to claim 1, wherein, when said target applied power is maximum rated power, said controller (CT) sets said power-supply frequency in a vicinity of a resonant frequency of said discharging load (1).

4. The plasma-generation power-supply device according to claim 1,

wherein said alternating-current power-supply (IV) is formed of an inverter, and said alternating output is a pulse output,

and wherein when

Cg: an electrostatic capacity value of a dielectric included in said discharging load,

Ca: an electrostatic capacity value of a gas region included in said discharging load,

Cp: a floating electrostatic capacity value in parallel with said discharging load,

V*: a discharge maintaining voltage,

L: an inductance value in a circuit including said discharging load,

f: said power-supply frequency, and

Cβ: an electrostatic capacity in a non-discharging state,

then, said controller (CT) varies said power-supply frequency and a duty of said pulse output within a stable control region that is surrounded by:

a characteristic curve of applied power that is obtained when said power-supply frequency is varied with said duty of said pulse output fixed at a maximum value;

a curve representing 0.9 times a curve of an applied power Poz that is given by an expression below

[Expression 1]

$$Poz = 4Cg(V^*)^2 f\left(\frac{Cg}{Cg + Cp - \frac{1}{L(2\pi f)^2}} - \left(1 + \frac{Ca}{Cg}\right)\right) \quad \cdots (4);$$

and,

a straight line representing a resonant frequency fmax in the non-discharging state that is given by an expression below

[Expression 2]

$$f_{\max} = \frac{1}{2\pi\sqrt{LC_\beta}} \quad \cdots (5).$$

5. The plasma-generation power-supply device according to claim 4, wherein said controller varies said power-supply frequency and said duty along a curve that is defined by:

a segment, located on a higher-frequency side of a resonance point, of a characteristic curve of the applied power that is obtained when the frequency is varied with the duty of said pulse output fixed at a value from 80% to 90% of the maximum value; and

a straight line that represents a frequency selected from a range between the value of said resonant frequency fmax in the non-discharging state defined by said expression (5) and a value corresponding to 80% of the fmax.

6. The plasma-generation power-supply device according to claim 1, further comprising resonance means (FL) that causes an alternating voltage outputted from said alternating-current power-supply (IV) to jump by resonance and applies the jump voltage as a load voltage to said discharging load,

wherein said alternating-current power-supply (IV) is connected electrically directly to said resonance means (FL).

7. The plasma-generation power-supply device according to claim 6, wherein said resonance means (FL) comprises a reactor (FL, FL1) connected in series or parallel with said discharging load (1).

8. The plasma-generation power-supply device according to claim 1, comprising a current detector (DT) that detects a current of said discharging load (1),

wherein said controller (CT) varies the power-supply frequency of said alternating-current power-supply (IV) on the basis of the current detected by said current detector (DT).

9. A plasma-generation power-supply device that drives a discharging load (1) that generates a plasma, comprising:

an alternating-current power-supply (IV) that supplies power to said discharging load (1);

a variable passive element (VL) that varies a circuit constant of a circuit provided on an output side of said alternating-current power-supply (IV) and including said discharging load (1); and

a controller (CT1) that variably controls said variable passive element (VL),

said controller (CT1) variably controlling said variable passive element (VL) in accordance with a target applied power to said discharging load (1).

10. The plasma-generation power-supply device according to claim 9, wherein said controller (CT1) variably controls said variable passive element (VL) such that current is delayed in phase with respect to voltage at a power-supply output end of said alternating-current power-supply (IV).

11. The plasma-generation power-supply device according to claim 9, comprising a current detector (DT) that detects a current of said discharging load (1),

wherein said controller (CT1) variably controls said variable passive element (VL) on the basis of the current detected by said current detector (DT).

12. A plasma-generation power-supply device that drives a discharging load (1) that generates a plasma, comprising:

an alternating-current power-supply (IV) that supplies power to said discharging load; and

resonance means (FL) that causes an alternating voltage outputted from said alternating-current power-supply (IV) to jump by resonance and applies the jump voltage as a load voltage to said discharging load,

wherein said alternating-current power-supply (IV) is connected electrically directly to said resonance means (FL).

13. The plasma-generation power-supply device according to claim 12, wherein said resonance means (FL) comprises a reactor (FL) connected in series with said discharging load (1), and

said load voltage is obtained by resonance of a capacitive component of said discharging load (1) and said reactor (FL).

14. The plasma-generation power-supply device according to claim 12, further comprising a transformer (TR) that is provided on an input side of said alternating-current power-supply (IV) to boost a power-supply voltage supplied from outside of said plasma-generation power-supply device,

wherein said transformer has its primary side and its secondary side electrically insulated from each other.

15. The plasma-generation power-supply device according to claim 12, wherein said discharging load (1) is an ozonizer.

16. The plasma-generation power-supply device according to claim 12, wherein said resonance means (FL) comprises a reactor (FL) connected in series with said discharging load (1), and said load voltage is obtained by resonance of a capacitive component of said discharging load (1) and said reactor (FL),

and wherein when a ratio of said load voltage with respect to the output voltage of said inverter is defined as a voltage jump rate,

then, a power-supply frequency of said alternating-current power-supply is set approximately equal to a resonant frequency of a circuit including said discharging load, and said output voltage is selected such that said voltage jump rate takes a value in a vicinity of a minimum value on a characteristic curve of said voltage jump rate with respect to said power-supply voltage.

17. The plasma-generation power-supply device according to claim 12,

wherein said alternating-current power-supply (IV) is formed of an inverter, and

said resonance means (FL) comprises a reactor (FL) connected in series with said discharging load (1), and said load voltage is obtained by resonance of a capacitive component of said discharging load (1) and said reactor (FL),

and wherein, when

a ratio of said load voltage with respect to the output voltage of said inverter is defined as a voltage jump rate,

Cg: an electrostatic capacity value of a dielectric included in said discharging load,

Ca: an electrostatic capacity value of a gas region included in said discharging load, and

Cp: a floating electrostatic capacity value in parallel with said discharging load,

and a power-supply frequency of said alternating-current power-supply is set approximately equal to a resonant frequency of a circuit including said discharging load, and when a minimum value M00 of said voltage jump rate on a characteristic curve of said voltage jump rate with respect to said power-supply voltage is defined by an expression below

[Expression 3]

$$M00 = \sqrt{2}\left(\left(\left(1+\frac{Ca}{Cg}\right)\left(1+\frac{Cp}{Cg}\right)-\frac{1}{2}\right)+\sqrt{\left(\left(1+\frac{Ca}{Cg}\right)\left(1+\frac{Cp}{Cg}\right)-\frac{1}{2}\right)^2-\frac{1}{4}}\right)$$
$$\cong 2\sqrt{2}\left(\left(1+\frac{Ca}{Cg}\right)\left(1+\frac{Cp}{Cg}\right)-0.5\right) \qquad \cdots(10)$$

then, said load voltage is set to be larger than $(\sqrt{2}/4)\bullet M00$ times said inverter's bus voltage and smaller than $\sqrt{2}\bullet(M00+2)$ times said inverter's bus voltage.

18. The plasma-generation power-supply device according to claim 12,

wherein said alternating-current power-supply (IV) is formed of an inverter, and

said resonance means (FL) comprises a reactor (FL) connected in series with said discharging load (1), and said load voltage is obtained by resonance of a capacitive component of said discharging load (1) and said reactor (FL),

and wherein when

a ratio of said load voltage with respect to the output voltage of said inverter is defined as a voltage jump rate,

Cg: an electrostatic capacity value of a dielectric included in said discharging load,

Cp: a floating electrostatic capacity value in parallel with said discharging load,

Vd: a bus voltage of said inverter, and

V*: a discharge maintaining voltage,

then, a power-supply frequency of said alternating-current power-supply is set approximately equal to a resonant frequency of a circuit including said discharging load, and the bus voltage Vd of said inverter is set in a range defined by an expression below, as compared with said discharge maintaining voltage V*,

[Expression 4]

$$\frac{4V^*}{1+\dfrac{Cp}{Cg}} > V_d > \frac{V^*}{2\left(1+\dfrac{Cp}{Cg}\right)} \qquad \cdots(14).$$

19. The plasma-generation power-supply device according to claim 17, wherein said discharging load (1) is a cylindrical multi-tube type ozonizer that has a plurality of coaxially placed cylindrical electrodes, with a gap interval of 0.6 mm or less, and

said load voltage is set to be larger than one times said inverter's bus voltage and smaller than six times said inverter's bus voltage.

20. The plasma-generation power-supply device according to claim 18, wherein said discharging load (1) is a cylindrical multi-tube type ozonizer that has a plurality of coaxially placed cylindrical electrodes, with a gap interval of 0.6 mm or less, and

the bus voltage of said inverter is set to be larger than 0.5 times said discharge maintaining voltage and smaller than two times said discharge maintaining voltage.

21. The plasma-generation power-supply device according to any of claims 1, 9, and 12, wherein said discharging load (1) is an ozonizer that has a gap interval of 0.6 mm or less and operates with a material gas containing oxygen at an atmospheric or higher gas pressure.